Purdue Journal of Service-Learning and International Engagement

Volume 5 | Issue 1 Article 5

2018

Transcribing Braille Code: Learning Equations Across Platforms

Deegan Atha
Purdue University, datha@purdue.edu

Courtney Balogh
Purdue University, cbalogh@purdue.edu

TRANSCRIBING BRAILLE CODE:

Learning Equations Across Platforms

Deegan Atha and Courtney Balogh, *College of Engineering*

STUDENT AUTHOR BIO SKETCHES

Deegan Atha, a graduating senior in electrical engineering and a future engineer, is interested in human-centered design and developing technology that helps students engage and be successful in STEM.

Courtney Balogh, a junior in mechanical engineering, is interested in human-centered design and the importance it plays in product development. Deegan and Courtney are members of the Purdue EPICS project, Learning Equations Across Platforms (LEAP). They partnered with the Indiana School for the Blind and Visually Impaired (ISBVI) to develop a braille transcription device and web application that converts braille to print in real time.

INTRODUCTION

"Math achievement of blind students has been consistently behind that of their sighted peers. In recent years, very little research and product development has been done to improve this situation" (APH, 2017). The Indiana School for the Blind and Visually Impaired (ISBVI, n.d.) educates over 160 students from preschool to twelfth grade. As students progress into more advanced mathematics courses, there is an increase in math characters needed, whether learning in braille code or print. This increase leads to more complex braille characters. Educators who are sighted invest much of their time to transcribe the students' work into print for grading. This transcription process can be complex, especially to someone unfamiliar with braille code. The Learning Equations Across Platforms (LEAP) team is working with Ms. Lisa Starrfield's math classes to develop a device to aid in the transcription process for sighted educators. Starrfield has advanced knowledge of braille code and has been teaching math at ISBVI for many years. In conversation she describes not having a "shared medium to communicate [with students] without a transcriber" as a barrier between students and teachers.

Deegan and Courtney enrolled in EPCS 490, a senior design course, and EPCS 302, a junior-level course, respectively. EPICS courses can be taken for multiple semesters for any grade classification or major. EPICS provided a service-learning space and resources for the LEAP team to develop this project. Each semester, students are required to complete professional development hours (PDH), which could range from watching an online video lecture to attending an Introduction to Electronics Workshop in the lab. These PDH allowed the team to learn valuable skills and complete the project successfully.

Coursework and past experiences paved the way for the EPICS experience for both Deegan and Courtney. While in college, Deegan was involved with an after-school service mentoring program for elementary students, which provided background working with students and teachers. Courtney was involved with Project Lead the Way courses at her high school, which provided a picture of how engineering can benefit people. Both

Figure 1 (banner image, above). An Apex Braille Notetaker, which contains a single line of refreshable braille and a braille keyboard.

wanted to find a way to use their engineering education to help people, and the EPICS LEAP team provided this opportunity. It became an important part of their college careers. The primary objective of this project was to help bridge a communication gap between students and teachers in the classroom.

DESCRIPTION

The idea of starting the EPICS LEAP team came from Lisa Starrfield, a Purdue alumnus. She was familiar with the EPICS program and suggested the initial project idea. The Indiana School for the Blind and Visually Impaired (ISBVI) is located in Indianapolis, Indiana, and provides services to people ages 3 to 22 with a wide range of visual impairments. Their top priority is to connect with and serve more people throughout Indiana, "thereby furthering [their] national prominence as a center of excellence for the education of children who are blind and visually impaired" (ISBVI, n.d.). The LEAP team works with Lisa Starrfield's math classes. The clients are junior high– to high school–aged blind students, as well as their teachers.

The first-semester team defined the problem and determined the user needs and specifications that now form the LEAP team. The project addresses the complex braille code and the time-consuming transcription that must take place for sighted teachers to grade work and give feedback. The LEAP team implemented their design with the use of 3-D printed parts, a Particle Photon microcontroller, and a webserver and database structure.

Math is a visual subject, and the written component of math is vertical, with each step in a calculation on the line below the previous step. Because of the vertical nature of braille, the students' electronic braille devices, such as the Apex Notetaker pictured in Figure 4, are not as helpful for math as they can only display one line of braille at a time. Students therefore still use a Perkin's Brailler for math, pictured in Figure 5. This device physically creates braille on a piece of paper. The device is not electronic, and many educators, especially new teachers and public school teachers, are fully sighted and in the process of learning braille. For high school mathematics, these teachers typically transcribe the braille to print by hand before reviewing a student's work. This is a time-consuming process and limits the amount of in-class feedback an educator can provide to a student.

Figure 2. LEAP device retrofitted onto Perkins Braille Writer.

COMMUNITY IMPACT

The project impacts the community partner in two ways. The first is to help educators teach students math by removing the time-consuming burdens of transcribing braille to print. The second is to engage Ms. Starrfield's students in STEM and technology development in a collaborative university setting. By engaging the students, the system will improve. The better the system, the more excited and engaged the students become.

Ensuring the Product's Functionality

The first objective requires a well-tested system working within the school. The most critical capability of the system is to be able to transcribe Nemeth input into standard print accurately and in real time. A system unable to perform this function causes problems because a teacher may think that a correct answer is wrong. Many tests at the school and in the lab were performed to verify the accuracy of the transcription; however, mapping is not straightforward. Braille symbols, as a matrix of 6 dots, can only represent 63 combinations. Therefore, braille cells are used in combination with other braille cells to be able to get the combinations needed for all the special characters in math. This means that a single braille cell in isolation could transcribe to one print character, but when combined with some combination of other braille cells, it could transcribe to a completely different print character.

Transcribing all symbols is the ultimate goal, but we focused on algebra and precalculus transcription accuracy tests first. The team would type many different sequences of braille cells to confirm that all transcriptions were correct. Additionally, at design reviews and on visits to the school, students would use the device and type documents to verify the accuracy of the outputs. As a final check, the web application for the teacher displays both the print and a digital image of the braille side-by-side. This verifies what the student typed in braille if a mistake in transcription is identified.

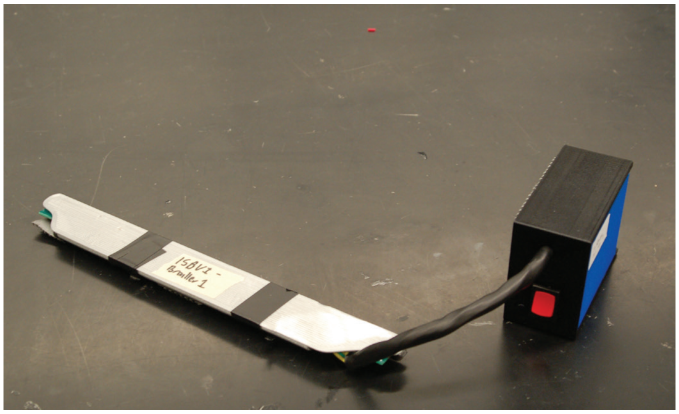

Figure 3. LEAP device with 3-D–printed coverings over the electronics.

One of the most significant technical challenges was to integrate the device within the school's IT infrastructure. Wi-Fi signals do not travel well because it's an older school. The small microcontroller used as the processing unit for the device attached to the Perkin's Brailler does not contain an antenna of smartphone or laptop quality, so it had difficulty connecting in several areas in the classrooms. We worked with the school administration to get a Wi-Fi router in Ms. Starrfield's room to improve the Internet reliability for the device.

The impact on the classroom will be measured based on how teaching can be enhanced. Two important metrics include (1) how much time is saved grading by having the work already transcribed, and (2) the change in frequency and length of time spent helping a student in class on a problem by having the transcription immediately available. If the system is found to be effective at a public school, a third metric would include how many days or class periods a student has to be pulled out of class for additional help due to materials not being transcribed. If this is decreased, the teacher would be able to more effectively interact between the student's braille and print mediums.

As Ms. Starrfield said:

> Most people who teach visually impaired students math are math teachers and do not know the braille code for math. There is no shared medium to communicate without a transcriber. The LEAP team project will provide a digital transcription of a student's work in real time, allowing a teacher unfamiliar with Nemeth to correct misunderstandings and grade assignments immediately without waiting for an intermediate.

We plan to further test the device at the school as the design progresses. The first phase of testing will involve proving a robust functionality. This includes addressing questions such as, "Will the microcontroller connect to the server efficiently every time the device is powered on?" and "Will the mechanical piece in the trough of the brailler stay in place throughout use?" Long-term testing will determine the impact of the device in the classroom and prove its viability in other classrooms. This testing will focus on time saved by immediate transcription when used elsewhere. As we move forward, we will seek assistance from advisors in the EPICS program.

Engaging Students in STEM

Our second objective is to engage Ms. Starrfield's students. At the start of each semester, our EPICS team travels to the school and interacts with the students in a classroom by having the students test the device and talk about their experiences. Some ISBVI students travel to Purdue for a design review. For these, students review the project with industry representatives and ask questions, as well as learn how the technology was developed. On one of our trips to the school, a student demonstrated to Deegan how he navigated his computer very quickly—faster than Deegan could. They talked about how he was learning to code and what he could do with what he learned. Many students talk about how they hope to go to Purdue and study engineering. One of the primary things that Ms. Starrfield wants to relay to her students is that regardless of their visual capabilities, they all can pursue a STEM degree from a top-tier institution like Purdue. Participating on an engineering project has helped her convey that message to her students.

STUDENT AUTHOR IMPACT

This project provided an excellent space for academic learning while completing a service-oriented project. The EPICS program provided Courtney and Deegan

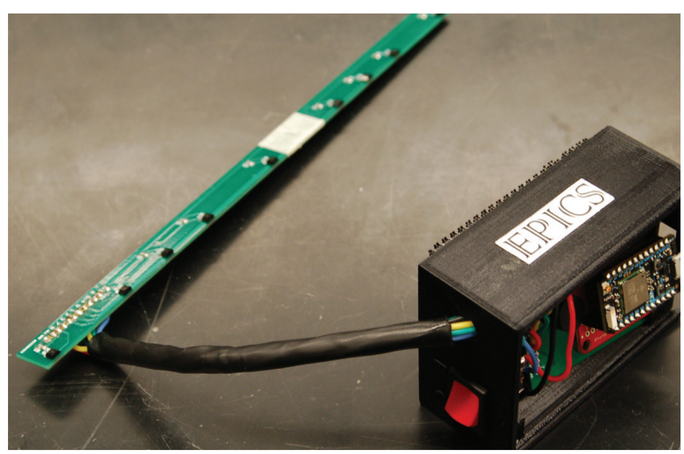

Figure 4. LEAP device without 3-D–printed pieces showing the PCB and microcontroller.

with a real-world problem and allowed them to use their training to develop a solution. Courtney gained experience with various computer-aided drawing (CAD) programs and has implemented the designs into the project through 3-D printing. Being able to work a design from a sketch, to a CAD model, to a physical model is great practice for future applications. Deegan gained experience with electronic and software development. He has developed software at multiple levels, from software for a microcontroller, to a backend server and database development, to a client-side web application. These experiences are important in obtaining internships and eventual employment upon graduation.

The EPICS program does not require any preparation before participating in a project because most skills can be learned from past team members or advisors or through professional development hours. When Courtney entered as a freshman, she had very little CAD and design experience. Through talking with upperclassmen and learning on her own, she obtained the skills she needed to complete her project tasks. Deegan joined EPICS as a sophomore with some engineering coursework and experience; however, he needed to learn many aspects of software development. One of the most helpful things for him was having upperclassman as part of the team to help teach and guide on the project.

Courtney and Deegan learned academically, professionally, and personally. They gained knowledge about the blind and visually impaired community, along with challenges faced in the classroom for students who are blind. This experience stressed the importance of accessibility and working to design for all users. It all goes back to keeping the project partners in mind and making sure to listen to their needs. Moving through the project design process helped Courtney and Deegan learn to plan and adjust to realistic goals. When issues come up from the design process, it's important to be flexible and adjust where needed.

Figure 5. A Perkin's Braille Writer, which prints physical braille onto a piece of paper through typing.

Courtney would ultimately like to be in a position in her career where she communicates with users, gets feedback, and improves designs to meet their needs. Deegan has accepted a job at NASA JPL with the robotics group. His experience with EPICS will be invaluable for his future career. Additionally, NASA and JPL have extensive STEM outreach programs, and Deegan plans to be involved with them.

Moving Forward

A minimum viable prototype is almost ready for testing within the school. Once this prototype is tested and verified by the school, iterations will be made to provide more features that are important to enhance functionality.

The LEAP team plans to continue partnering with the Indiana School for the Blind and Visually Impaired (ISBVI). First, a working prototype meeting all user needs and specifications will be provided, and iterations will be made from significant user testing and feedback. When the LEAP project is complete from both the perspective of the school and EPICS, a new project could be discussed.

CONCLUSION

EPICS has 40 teams and over 100 ongoing projects. For students interested in service- learning, EPICS provides opportunities to work with community partners. Any student can join and provide value to a project. By staying with the same project for multiple semesters, Courtney and Deegan were able to get to know the students and teachers better. Additionally, they had the opportunity to focus on several aspects of the design process. The service-learning experience provided by EPICS has been instrumental in both of their college experiences and future career plans. They hope other students will pursue similar opportunities. Students who wish to be involved with the LEAP project should sign up for an EPICS semester course with the ISBVI team.

ACKNOWLEDGMENTS

Courtney and Deegan would like to thank Lisa Starrfield and the Indiana School for the Blind and Visually Impaired for partnering with them on this project and for providing them with valuable insights for their product design. To Andrew Pierce, the advisor for the ISBVI team and writing mentor, for providing guidance and help whenever needed. To Patricia Darbishire, as an additional writing mentor. Finally, to all team members who have worked on this project. Without their help, the project could not have been completed.

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